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Integrating Ecosystem Considerations into Groundfish Fisheries Management off Alaska, USA

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Abstract **--** Ecosystem considerations factor into the management of groundfish fisheries in the North Pacific Ocean off Alaska, USA. The Council's ecosystem-based management approach involves public participation, reliance on scientific research and advice, conservative catch quotas, comprehensive monitoring and enforcement, bycatch controls, gear restrictions, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations. The most basic ecosystem consideration employed is a precautionary approach to extraction of fish resources. Off Alaska, all groundfish stocks are considered healthy, while providing sustained yields of about two million metric tons annually. Management measures are also taken to minimize potential impacts of fishing on seafloor habitat and other ecosystem components such as marine mammals and seabirds.

Ecosystem-based management strategies have been widely adopted throughout the United States for terrestrial and freshwater aquatic systems, but are just beginning to be applied to marine ecosystems (National Research Council, 1999). Fisheries can impact ecosystems in numerous ways. Populations of fish and other ecosystem components can be affected by the selectivity, magnitude, timing, location, and methods of fish removals. Fisheries can also impact ecosystems by vessel disturbance, nutrient cycling, introduction of exotic species, pollution, unobserved mortality, and habitat alteration. An ecosystem-based management strategy for marine fisheries would be to minimize potential impacts while at the same time allowing the extraction of fish resources at levels sustainable for both the fish stock and the ecosystem. Management measures consistent with an ecosystem-based strategy include conservative and precautionary catch limits, comprehensive monitoring and enforcement, bycatch controls, gear restrictions, temporal and spatial distribution of fisheries, marine protected areas, and other considerations.

The North Pacific Fishery Management Council has been developing an ecosystem-based management approach for management of North Pacific groundfish (e.g., pollock, cod, flatfish) fisheries. The Council is a regional organization established by the Magnuson-Stevens Fishery Conservation and Management Act in 1976 when the United States extended its fisheries jurisdiction out to 200 nautical miles (371 km). The Council, together with the National Marine Fisheries Service, has primary responsibility for groundfish management in the Gulf of Alaska, Bering Sea, and Aleutian Islands area, encompassing about 900,000 square nautical miles (2,680,000 km^2). Conservative management policies, such as catch limits and marine protection areas, were implemented with adoption of the first fishery management plans. The goals of the fishery management plans include conserving fishery resources for optimum yield, maintaining productive fish habitats, and minimizing interactions with other elements of the ecosystem.

The Council's goals and policies, which are consistent with a precautionary approach and ecosystem-based management, have resulted in sustainable fisheries. All groundfish stocks are considered relatively healthy after 20 years of sustained annual harvests of about 2 million mt. No fish stocks have been deemed overfished in a recent evaluation of the status of U.S. fisheries (National Marine Fisheries Service, 1998a).

When revised overfishing definitions were implemented in 1999, only one fishery resource in the region (Bering Sea Tanner crab) was determined to be below its minimum stock size threshold, and an aggressive rebuilding plan is being developed for this stock.

Although fish stocks remain healthy, concerns about the impacts of fish removals on other components of the ecosystem have motivated the Council to continue development of a more ecosystem-based management strategy. This paper reviews the Council's approach to date, and explores further progress towards integrating ecosystem considerations into management of groundfish fisheries.

Precautionary and Conservative Catch Limits

Total removals of groundfish are controlled by annual catch limits established for each stock. For each target stock, three harvest levels are set, corresponding to the overfishing level (OFL), the acceptable biological catch (ABC) and total allowable catch (TAC). TACs are essentially annual catch limits for the fishery, and are established at or below the ABC. ABCs define acceptable harvest levels from a biological perspective, and OFL defines the unacceptable harvest level. Specification of harvest limits is done in a precautionary manner, due to a number of reasons as explained below.

Harvest rate specifications are more conservative when less information is available. The maximum allowable rates are prescribed in descending order of preference, corresponding to descending order of information availability (Thompson, 1996). Additionally, maximum sustainable yield (MSY) is treated as a limit, rather than a target. For most stocks, ABC is based on a rate less than or equal to $F_{40\%}$, which is the fishing mortality rate associated with an equilibrium level of spawning per recruit equal to *40%* of the equilibrium level of spawning per recruit in the absence of any fishing. In other cases where less information is available about the stock, ABC is generally based on the three-fourths of the natural mortality rate (M). Both the $F_{40\%}$ and 0.75M rates are considered to be conservative harvest rates for most groundfish stocks (Clark, 1993; Rosenberg and Restrepo, 1995). To further minimize the possibility of catches jeopardizing a stock's long term productivity, there is a buffer established between ABC and OFL. For most stocks OFL is defined based on a $F_{35\%}$ rate.

Harvest rates used to establish ABCs are reduced at lower than average stock size levels, thereby allowing rebuilding of less abundant stocks. If the biomass of any stock falls below Bmsy or $B_{40\%}$ (the long-term average biomass that would be expected under average recruitment and $F=F_{40\%}$), the fishing mortality rate is adjusted relative to stock status. This serves as an implicit rebuilding plan should a stock fall below a reasonable abundance level. Conservative harvest policies have helped to restore yellowfin sole (<u>Pleuronectes</u> <u>asper</u>) and Pacific Ocean perch (<u>Sebastes</u> <u>alutus</u>) stocks that were depleted by foreign fleets in the 1960's. For other stocks, such as Greenland turbot, <u>Reinhardtius hippoglossoides</u>, even very conservative harvest rates have not resulted in increased recruitment.

As a result of these definitions, specified harvest rates for groundfish stocks are very low. Actual harvest rates are significantly lower for many species, as the TAC may be set much lower than ABC, and harvests may be less than TAC due to regulatory closures. All fish caught in any fishery (including bycatch), whether landed or discarded, are counted towards the TAC for that stock. Based on comprehensive onboard observer data and reports provided by the fleet, directed fisheries for each species or complex are closed before the TAC is reached, so that catches are maintained within biologically acceptable levels. Observer data provides for accurate and precise estimation of Alaska groundfish catch (Volstad et al., 1997). Because 100% mortality for all discards is assumed (some fish likely survive), actual removals may be lower than catch numbers indicate.

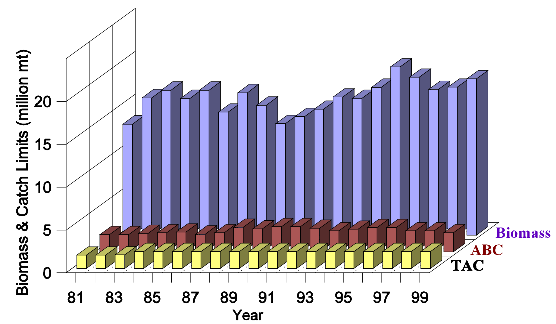

Figure 1. Catch specifications (TAC and ABC in mt) and exploitable biomass (mt) of Bering Sea and Aleutian Islands groundfish stocks, 1981-1999.

Additional precaution is incorporated at the catch specification level for Bering Sea/Aleutian Islands groundfish. Since 1981, the total annual allowable catch of groundfish for this region must fall within an optimum yield range of 1.4 to 2.0 million mt. This has limited the sum of TAC's for all species to 2 million mt per year, which has been considerably less than the sum of all ABCs (Figure 1). In some years, ABC's have totaled more than 2.8 million mt. As a result, many groundfish stocks, particularly flatfish stocks, have been exploited well below sustainable levels (Witherell, 1995).

Limits on bycatch and discards

The issues of bycatch, discard, and waste of fish resources stems from social, economic, and conservation concerns. From an ecosystem perspective, mortality of unwanted and prohibited species may reduce spawning potential, reduce biodiversity, alter regular paths of energy flow and balance, enhance the growth of scavenger populations, and add uncertainty to estimates of total removals. Fish are discarded for two reasons, either they are required to be thrown back due to regulations (prohibited species), or they are unwanted by that fishing vessel. In the North Pacific, discards of unwanted groundfish (so-called economic discards) result when fishermen do not have markets, sufficient equipment, time, or economic return to retain and process the catch (Queirolo et al., 1995). In the 1997 Bering Sea/Aleutian Islands fisheries, a total of 258,000 mt of groundfish was discarded, equating to about 15% of the total groundfish catch. Although this discard rate is much lower than most of the world's groundfish fisheries, which average about 19.9% discards (Alverson et al., 1994), the sheer volume of discards is troublesome to many people who consider economic discards as waste of food and as having an impact to the ecosystem.

Bycatch management measures implemented for groundfish fisheries of the eastern Bering Sea have focused on reducing the incidental capture and injury of species traditionally harvested by other fisheries. These species include king crab, Paralithodes and Lithodes spp.; Tanner crab, Chionoecetes spp.; Pacific herring, Clupea harengus pallasi; Pacific halibut, Hippoglossus stenolepis; and Pacific salmon and steelhead trout, Oncorhynchus spp. Collectively, these species are called "prohibited species," as they cannot be retained as bycatch in groundfish fisheries and must be discarded with a minimum of injury.

Bycatch controls were instituted on foreign groundfish fisheries prior to passage of the Magnuson Stevens Act in 1976 and have become more restrictive in recent years (Witherell and Pautzke, 1998). Bycatch limits are apportioned to specific groundfish target fisheries, and attainment of any apportionment closes that groundfish target fishery for the remainder of the season. Bycatch limits for 1998 Bering Sea and Aleutian Island groundfish trawl fisheries included 3,775 mt of halibut mortality, 1,697 mt of herring, 100,000 red king crabs, 2,850,000 C. bairdi crab, 4,654,000 C. opilio crab, 48,000 chinook salmon, and 42,000 other salmon. These limits equated to about 0.1% of the red king crab and C. opilio crab populations, 1.8% of the C. bairdi crab population, 1% of the herring biomass, and 1.3% of the halibut biomass. The impact of salmon bycatch on Alaska salmon populations remains unknown, but is thought to be <1% of the chum salmon population, and in the order of 2% to 4% of the adult chinook salmon population (NPFMC, 1999). To reduce the impact of bycatch on chinook salmon population, bycatch limits will be incrementally reduced to 29,000 salmon by the year 2003.

In addition to bycatch limits, gear restrictions and other regulatory changes have also been implemented to reduce bycatch and waste. Biodegradable panels are required for pot gear to minimize waste associated with so-called ghost fishing of lost gear. Tunnel openings for pot gear are limited in size to reduce incidental catch of halibut and crabs. Gillnets for groundfish have been prohibited to prevent ghost fishing and reduce bycatch of non-target species. With the implementation of an individual fishing quota system for halibut and sablefish longline fisheries in 1995, bycatch and waste were reduced because the race for fish was eliminated, allowing for more selective fishing practices (Adams, 1995). The Council recently approved a measure to prohibit the use of non-pelagic trawl gear for vessels targeting pollock in the Bering Sea, and made a concomitant reduction of allowable prohibited species bycatch.

To reduce discards, the Council adopted an improved retention and utilization program for all groundfish target fisheries. Beginning in 1998, 100% retention of pollock (Theragra chalcogramma) and Pacific cod (Gadus macrocephalus) was required, regardless of how or where it was caught. Only fish not fit for human consumption can be legally discarded. This measure has dramatically reduced overall discard of groundfish (Figure 2). For example in 1997, about 22,100 mt of cod (8.6% of the cod catch) and 94,800 mt of pollock (8.2% of the pollock catch) were discarded. In 1998, discard amounted to only 4,300 mt of cod (2.2%) and 16,200 mt of pollock (1.6%). A regulation requiring full retention of all demersal shelf rockfish species (e.g, yelloweye rockfish, Sebastes ruberrimus) was adopted in 1999. Rock sole (Lepidopsetta bilineata) and yellowfin sole retention will be required beginning in 2003; the delay will allow for development of new markets and gear technological responses by the vessels engaged in these fisheries. These retention requirements are expected to reduce overall discard rates (all species) from about 15% to about 5%.

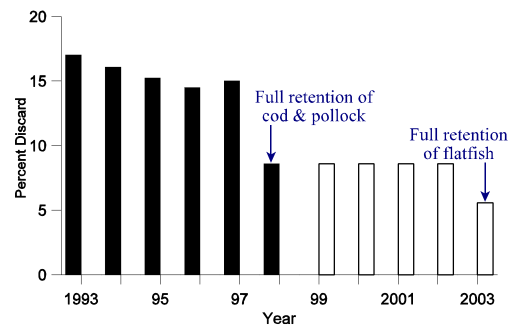

Figure 2. Total discard rates of Alaska groundfish, all areas and species combined, 1993-1998, with projections through 2003.

Marine Protected Areas

Several marine protected areas have been established to protect habitat for fish, crabs, and marine mammals (Figure 3). Adequate habitat is essential for maintaining productivity of fishery resources, and some species or life stages require particular habitats for food, reproduction, and shelter from predators. In the Bering Sea, three large areas have been closed to groundfish trawling and scallop dredging to reduce potential adverse impacts on vulnerable and essential habitat for crab and other resources. A limited amount of longlining for Pacific cod and halibut, as well as pot fishing for Pacific cod and crabs occurs within all three of these marine protected areas. In the Gulf of Alaska, several discrete trawl closure areas have been established around Kodiak Island to protect crab habitat. A very large no trawling area was established off Southeast Alaska, an area containing extensive coral distribution and other high relief habitat. Closure of Cook Inlet to bottom trawling has also been proposed to further protect crab habitat. One small area, a nearshore pinnacle off Cape Edgecumbe in southeast Alaska, has been closed to bottom fishing with all gear types.

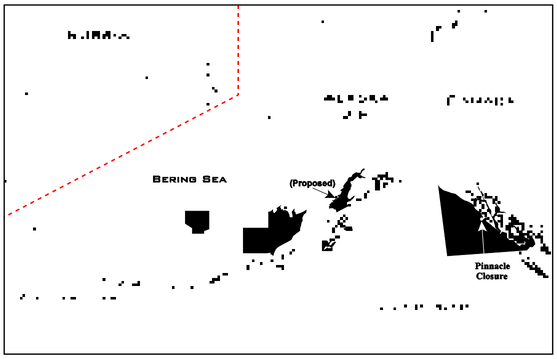

Figure 3. Location of marine protected areas off Alaska where trawling is prohibited year-round to protect fish and crab habitat.

These marine protected areas comprise a relatively large portion of the continental shelf, and in many respects, serve as marine reserves. In total, the three Bering Sea area closures encompass about 30,000 square nautical miles (89,500 km^2). To put this in perspective, this is an area more than twice the size of Georges Bank off the east coast of the United States. The Gulf of Alaska closures encompass about 47,000 square nautical miles (140,200 km^2), but a vast majority (80% - 90%) of this area is off the continental shelf (> 200 m). Lauck et al. (1998) recently suggested that marine reserves should be at least 20% of available habitat in order to be effective. The Bering Sea marine protection areas exceed this threshold by encompassing about 25% of the Bering Sea shelf where commercial quantities of groundfish can be taken with bottom trawl gear, based on interpolation of fishery location data from Fritz et al. (1997). Existing Gulf of Alaska closure areas encompass less than 10% of the trawlable shelf area.

The Magnuson-Stevens Act recently required that all fishery management plans include a description and identification of essential fish habitat, adverse impacts, and actions to conserve and enhance habitat In 1998, the Council defined essential fish habitat based on general fish distribution. Maps of these areas will be useful for understanding potential threats from proposed development and other activities. The next step is to identify habitat areas of particular concern based on ecological function and vulnerability to anthropogenic impacts. An example would include areas with slow growing corals that are extremely sensitive to impacts. Once these areas have been identified, potential threats due to fishing activities can be evaluated and additional measures implemented as needed. Because the Council has found marine protected areas to be a useful tool in managing bycatch and habitat protection, it is likely that additional areas will be established.

Marine Mammal and Seabird Considerations

Measures have been implemented to reduce potential impacts of localized depletion of prey for higher trophic levels. For example, because pollock is a primary prey item for endangered Steller sea lions (Eumetopias jubatus), it was determined that pollock fisheries could potentially jeopardize the continuing existence of the sea lions and impact their recovery (National Marine Fisheries Service, 1998b). To address these concerns, a number of precautionary management measures have been implemented. The TACs for pollock, and Atka mackerel, Pleugrammus monopterygius, (both important prey for sea lions) were spatially and seasonally apportioned into smaller sub-TACs to prevent prey removals from occurring all at once, and in localized areas. In 1999, all pollock fishing was prohibited in the Aleutian Islands region to eliminate any potential competition with sea lions.

Area closures have also been implemented to prevent disrupting marine mammals at rookeries and haulouts, and to reduce competition from fisheries. To protect Pacific walrus (Odobenus rosmarus), fishing vessels are prohibited in that part of the Bering Sea within twelve miles of Round Island, the Twins and Cape Pierce in northern Bristol Bay during the summer. To protect Steller sea lions, no trawling is allowed year round within 10 nautical miles (18.5 km) of numerous Steller sea lion rookeries and haulouts (Figure 4). In addition, a number of these no trawl zones extend out to 20 nautical miles (37 km) on a seasonal basis.

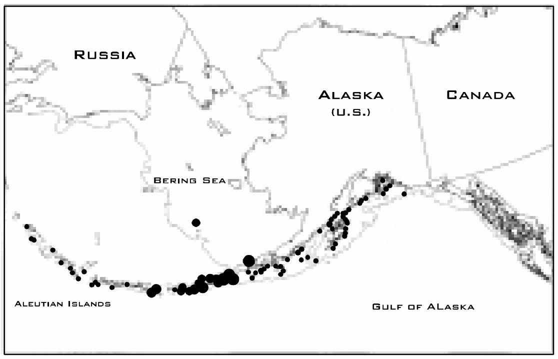

Figure 4. Location of the zones around Steller sea lion rookeries and haulouts where trawling is prohibited to reduce competition for prey.

In 1997, the Council adopted a regulation that prohibits directed fishing for forage fish, which are prey for groundfish, seabirds, and marine mammals. Under this amendment, protection is provided for forage fish species such as capelin (Mallotus villosus) and a host of other forage species including euphausiids (krill). Limited commercial fisheries for Pacific herring have traditionally been prosecuted in State waters, so herring was the only forage fish species exempted from the regulation. The Council took this proactive approach by preventing fisheries for important forage species from expanding or developing.

Regulations have also been established to reduce direct mortality of mammals and seabirds. Incidental catch limits have been established for Steller sea lions and the endangered short-tailed albatross, Diomedea albatrus. Concern for the incidental bycatch of seabirds led to regulations requiring deterrent devices be employed on groundfish longline vessels beginning in 1997. Approximately 9,600 seabirds (including about 1 albatross per year) are incidentally killed in Alaska groundfish fisheries each year (Wohl et al., 1995). It is hoped that these deterrent devices, which are actively being developed and improved upon by fishermen, will significantly reduce incidental mortality.

Continued Progress Towards Ecosystem-Based Management

Although fish stocks remain healthy, concerns about the impacts of fish removals on other components of the ecosystem have motivated the Council to continue development of a more ecosystem-based management strategy. This development has progressed at all levels, from science to policy making. Since 1995, the groundfish plan teams have prepared an Ecosystem Considerations section to supplement the annual Stock Assessment and Fishery Evaluation report (e.g., NPFMC, 1998). This chapter provides an annual assessment of the ecosystem, a review of recent ecosystem-based management literature, updates of ongoing ecosystem research, local observations from coastal people and fishermen, and new information on the status of seabirds, marine

Table 1. Draft ecosystem-based management policy of the North Pacific Fishery Management Council.

Definition: Ecosystem-based management, as defined by the NPFMC, is a strategy to regulate human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific, covering the Gulf of Alaska, the Eastern and Western Bering Sea, and the Aleutian Islands region.

Objective: Provide future generations the opportunities and resources we enjoy today.

Goals:
1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability.
2. Maintain and restore habitats essential for fish and their prey.
3. Maintain system sustainability and sustainable yields of resources for human consumption and non-extractive uses.
4. Maintain the concept that humans are components of the ecosystem.

Guidelines:
1. Integrate ecosystem-based management through interactive partnerships with other agencies, stakeholders, and public.
2. Utilize sound ecological models as an aid in understanding the structure, function, and dynamics of the ecosystem.
3. Utilize research and monitoring to test ecosystem approaches.
4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.

Understanding:
1. Uncontrolled human population growth and consequent demand for resources are inconsistent with resource sustainability.
2. Ecosystem-based management requires time scales that transcend human lifetimes.
3. Ecosystems are open, interconnected, complex, and dynamic; they transcend management boundaries.

mammals, habitat and other components of the North Pacific ecosystem. Future Ecosystem Considerations chapters will include more data analysis, such as standardized ecosystem status and trend indicators.

In 1996, the Council established an Ecosystem Committee to discuss possible approaches to incorporating ecosystem concerns into the fishery management process. The committee has held workshops on ecosystem research, held several meetings to discuss essential fish habitat, and has hosted numerous informal discussions on ecosystem-based management and habitat concerns. A major role of this committee has been to provide the Council and stakeholders with information on ecosystem-based management in the North Pacific. The committee identified primary principles and elements of ecosystem management from scientific literature (e.g, Grumbine, 1994; Mangle et al., 1995; Christiansen et al., 1996) to serve as draft policy for ecosystem-based management of North Pacific fisheries (Table 1). The committee also provides feedback to scientists regarding research needs.

Discussion

The Council has made significant progress towards incorporating ecosystem considerations into management of groundfish fisheries. Steps have been taken to lessen human impacts on the environment due to fishing, while at the same time providing sustained yields of fishery resources. Unlike many groundfish stocks in other areas of the world, stocks off Alaska remain relatively abundant. Catches of groundfish have been sustained at about 2 million mt over the past 20 years, despite many restrictions implemented to reduce fishing impacts on other ecosytem components.

The most basic ecosystem consideration employed by the Council is a precautionary approach to extraction of fish resources. The precautionary principle was developed over the past 10 years as a policy measure to address sustainability of natural resources in the face of uncertainty. Because precise impacts caused by human activity cannot be known with certainty, a more cautious approach is required (Dovers and Handmer, 1995), particularly when there is a high level of uncertainty and there are large (potentially irreversible) costs if a mistake is made (Garcia, 1995). Fisheries management around the world has traditionally been based on a preventative and trial-and-error approach, yet the collapse of some fisheries indicates that a more precautionary approach should have been applied. New national and international fishery legislation is pushing fishery management towards a new paradigm whereby MSY is treated as a limit to be avoided, rather than a target that can be exceeded. Mace (1999) refers to this system as one of conscious under-exploitation of natural marine resources so that marine ecosystems are preserved in perpetuity while still contributing to food production, recreation, and other human uses. If fisheries are managed sustainably using a precautionary approach, it is likely that the overall ecosystem processes, ecosystem integrity, and biodiversity are also protected to some degree.

Although measures implemented to date have been successful at achieving their objectives, ecosystem-based management is an adaptive process. Effective ecosystem-based management of fisheries will require periodic evaluation and modification to incorporate new scientific information as it becomes available. Additionally, ecosystems are not static, and human impacts also change with technology and continued population growth. Ocean conditions can cause significant, rapid, and sometimes unexpected changes in ecosystem components. Because so little is known about marine ecosystems, an adaptive and precautionary approach should be used for all fishery management policies.

Acknowledgments

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